REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 19. Period--January 1 to March 31, 1946

Compiled by R. T. Cotton, Entomologist
Cereal and Forage Insect Investigations
Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture
Manhattan, Kansas

The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 19. Period--January 1 to March 31, 1946

Compiled by F. T. Cotton, Entomologist
Cereal and Forage Insect Investigations
Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture
Manhattan, Kansas

The material in this report consists largely of unpublished data and should be kept confidential. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

WHEAT STORAGE

Studies on the Fluctuations of Insect Populations in Wheat Stored under Different Systems of Management*

The study on the fluctuations of insect populations in wheat stored in Ever-Normal granary-type bins has been continued during the quarter. Five-probe samples were taken at monthly intervals from the upper southwest quadrant of 35 bins in the Management Series, and the number of insects by species was determined for each sample. This study has been in progress since May, 1943, and the data have been included in previous quarterly reports. A summary of the data obtained since July 1, 1945 is given in table 1. The population in the untreated 11.5 per cent wheat reached the highest level yet recorded in this study on March 2, 1946.

The comparative abundance of the different species during the period January 1 to March 31 is given in table 2. It should be noted that most of the insects occurred in the untreated control bins of 11.5 per cent moisture. An extremely high infestation of the red flour beetle has developed in them during the winter months.

---

* -- Reported by H. H. Walkden, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine in Cooperation with the Bureau of Plant Industry, Soils, and Engineering.

WHEAT STORAGE

Studies on the Fluctuations of Insect Populations in Wheat Stored under Different Systems of Management*

The study on the fluctuations of insect populations in wheat stored in Ever-Normal granary-type bins has been continued during the quarter. Five-probe samples were taken at monthly intervals from the upper southwest quadrant of 36 bins in the Management Series, and the number of insects by species was determined for each sample. This study has been in progress since May, 1943, and the data have been included in previous quarterly reports. A summary of the data obtained since July 1, 1945 is given in table 1. The population in the untreated 11.5 per cent wheat reached the highest level yet recorded in this study on March 2, 1946.

The comparative abundance of the different species during the period January 1 to March 31 is given in table 2. It should be noted that most of the insects occurred in the untreated control bins of 11.5 per cent moisture. An extremely high infestation of the red flour beetle has developed in them during the winter months.

---

* -- Reported by H. H. Walkden, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine in Cooperation with the Bureau of Plant Industry, Soils, and Engineering.

Table 1.--Summary of the insect populations in the upper southwest quadrant of steel and wood bins, Hutchinson, Kansas, 1945-1946.

Grain storage practice	1945 July 1	1945 July 15	1945 Aug. 1	Average number of insects per 1000 grams 1945 Aug. 15	1945 Sept. 1	1945 Sept. 15	1945 Oct. 6	1945 Oct. 20	1945 Nov. 3	1945 Dec. 1	1946 Jan. 2	1946 Feb. 2	1946 Mar. 2
1000-bushel steel bins													
No treatment:													
9.3% moisture	0'	0	0.6	1.2	1.6	3.4	3.8	2.6	4.0	1.8	0	0	0
	0.2"	1.0	3.0	2.6	3.4	0.4	4.4	1.6	0.6	0.4	0	0	0
11-11.5% moisture	0.2	1.2	4.0	18.6	13.6	20.8	45.8	31.8	20.4	45.2	86.4	65.2	90.4
	3.8	9.5	38.8	73.6	67.0	65.9	119.0	111.4	135.0	146.6	269.8	187.9	444.2
White walls and roof	0.2	0	0	0.6	0.8	1.0	2.8	4.0	1.6	2.8	0	0	0
	1.0	1.8	4.8	8.8	10.6	5.8	19.6	5.2	4.2	13.0	4.8	4.2	4.0
Fumigation in August	0	0.9	2.6	4.9_F	1.3	4.5	10.4	24.0_F(1)	2.3	31.8_F(1)	2.5	0.2	0
	1.9	7.9	9.9	20.3^F	2.0	0.7	7.6	9.3	1.4	40.9^F	23.1	0	0.1
Fumigation in September	0	0.2	1.4	3.8	8.8	21.3_F	0.2	0.6	2.8	2.8	0	0.2	0
	1.0	1.6	6.6	14.8	29.2	20.2^F	2.0	0.6	1.4	1.4	0.2	0.4	1.2
Fumigation in August and October	0.1	0	0.5	0.7_F	0	0	0.3_F	0	0	0	0	0	0
	0.1	2.2	1.5	4.6^F	0.2	0.7	0.8^F	0	0	0	0	0	0
Turn, clean, and fumigate in September	0	2.4	2.0	1.6	6.4_T	13.6_F	0	0	0	0	0	0	0
	0	1.6	2.8	0.4	1.6^T	0.8^F	0	0	0	0	0	0	0

Footnote (1) Dangerous insect populations developed in these bins, necessitating an additional fumigation.

(continued)

Table 1 (continued)

Grain storage practice	1945 July 1	July 15	Aug. 1	Aug. 15	Sept. 1	Sept. 15	Oct. 6	Oct. 20	Nov. 3	Dec. 1	1946 Jan. 2	Feb. 2	Mar. 2
	Average number of insects per 1000 grams												
2740-bushel steel bins													
No treatment:													
White walls and roof	0	0	0	0.1	0	0.9	1.7	1.2	0.5	0.1	0	0	0
	0.1	1.1	4.2	6.8	9.8	11.4	23.6	15.0	7.7	11.7	6.0	3.8	4.8
Painted white and grouped for shading	0	0	0	0	0.4	0.3	0.3	0.8	0.1	0.1	0	0	0
	0.6	0.5	1.6	2.1	2.1	2.6	2.6	2.9	2.0	1.2	1.5	3.1	4.6
Fumigation in August	0	0	0.5	0.8[F]	0.2	0.2	0.7	1.1	0.8	0.9	0.2	0	0
	0.7	1.0	1.9	2.8[F]	0.7	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.5
Fumigation in September	0	0	0.6	0.6	2.1	5.2[F]	0.1	0.4	0.3	0.5	0.3	0	0
	0.5	0.2	2.8	3.3	7.1	6.4[F]	0.2	0.2	0.1	0.1	8.5	0.1	0
Fumigation in August and October	0	0	0.5	1.7[F]	0	0	0.2[F]	0	0	0	0	0	0
	0	0.06	0.9	2.4[F]	0.1	0	0.1[F]	0	0	0	0	0	0

Legend: ' = Weevils: includes lesser grain borer and rice weevil. F = Grain fumigated.
" = Bran bugs: all species except the weevils. T = Grain turned and cleaned.

Table 1 (continued)

Country of origin	Total	Africa		America, North		America, South		Asia		Europe		Oceania		USSR		Stateless persons		Refugees, country unknown	
		F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
Grand total																			
Total																			
Under 1 year																			
1 year																			
2 years																			
3 years																			
4 years																			
5 years																			
6 years																			
7 years																			
8 years																			
9 years																			
10 years																			
11 years																			
12 years																			
13 years																			
14 years																			
15 years																			
16 years																			
17 years																			
18 years																			
19 years																			
20 years																			
21 years																			
22 years																			
23 years																			
24 years																			
25 years																			
26 years																			
27 years																			
28 years																			
29 years																			
30 years																			
31 years																			
32 years																			
33 years																			
34 years																			
35 years																			
36 years																			
37 years																			
38 years																			
39 years																			
40 years																			
41 years																			
42 years																			
43 years																			
44 years																			
45 years																			
46 years																			
47 years																			
48 years																			
49 years																			
50 years																			
51 years																			
52 years																			
53 years																			
54 years																			
55 years																			
56 years																			
57 years																			
58 years																			
59 years																			
60 years																			
61 years																			
62 years																			
63 years																			
64 years																			
65 years																			
66 years																			
67 years																			
68 years																			
69 years																			
70 years																			
71 years																			
72 years																			
73 years																			
74 years																			
75 years																			
76 years																			
77 years																			
78 years																			
79 years																			
80 years																			
81 years																			
82 years																			
83 years																			
84 years																			
85 years																			
86 years																			
87 years																			
88 years																			
89 years																			
90 years																			
91 years																			
92 years																			
93 years																			
94 years																			
95 years																			
96 years																			
97 years																			
98 years																			
99 years																			
100 years and over																			

[illegible] = Data not available [illegible]

[illegible] = Figures not available for this category

[illegible] = Figures not available for this country

[illegible] = Figures not available for this country

Table 2.--Comparative abundance of the species of stored grain insects found in the bins in the management series, Hutchinson, Kansas, 1946.

Species	Per cent of Total Jan. 2	Feb. 2	Mar. 2	Number Observed
Red flour beetle (*Tribolium castaneum* Hbst.)	41.8	36.8	55.8	5966
Long-headed flour beetle (*Latheticus oryzae* Waterh.)	22.8	20.7	17.5	2536
Lesser grain borer (*Rhyzopertha dominica* F.)	20.6	24.5	16.4	2499
Flat grain beetle (*Laemophloeus minutus* Oliv.)	13.3	16.1	9.9	1583
Saw-toothed grain beetle (*Oryzaephilus surinamensis* L.)	1.4	1.6	0.4	127
Dermestid larvae	0	0.3	0.5	33

Study of the Amount of Damage Caused by Insects in Wheat Stored in Steel Bins

This study was begun in June, 1943. Samples are drawn from the south quadrant of the bins once each year during the winter months to determine the comparative amounts of insect damage in wheat stored under different management practices. The damage is computed on a weight basis, and any kernel showing insect injury is classed as damaged, regardless of the extent. Insect damage determinations have been made in a total of 65 bins since this study was begun.

A summary of the data obtained from 28 bins is presented in table 3. Other bins in the management series showed similar trends. It should be borne in mind that the damage recorded in the table represents the maximum amount in the bin since the samples were taken in the portion of the grain mass where the greatest insect population was known to occur. It may be noted in table 3 that there has been a general increase in insect damage, with the rate of increase being greatest in those bins receiving no treatment. Attention is called to the fact that, even though the amount of insect damage was comparatively slight even in wheat receiving no treatment, the presence of large numbers of insects in it caused the grain to heat, with resultant crusting and molding of the surface grain. When samples are drawn from bins in this condition, both the musty odor of the surface wheat and that of the infested portion is imparted to the whole sample, causing it to be graded "sample grade". Past experience has shown that even though only a small portion of the wheat in a bin may be musty or sour, the whole mass is likely to be contaminated when the bin is emptied. For this reason the amount of indirect damage by insects is much greater than the amount of grain actually consumed.

In the last column of table 3, the total damage is indicated. This figure represents the amount of damaged wheat in average samples from the various bins, as determined by the Chicago Board of Review, and includes damage from any cause. Thus it is evident that the grain mass is much less affected by insects than that in the southwest quadrant.

The results of the insect damage study confirm previous conclusions regarding the various management practices, viz.: (1) fumigation in August and October prevents the establishment of serious insect infestation, thus keeping the amount of insect damage to a minimum; (2) fumigation in September was successful in controlling the infestation but permitted some damage to occur prior to fumigation because of the rapid increase of insect populations during August and early in September; (3) painting the bins white prevented damage for two seasons but failed in the third; (4) the greatest amount of damage, as was expected, occurred in the uncontrolled check bins of 11.5 per cent moisture; (5) comparatively little damage occurred in wheat of 9 per cent moisture.

Study of the Amount of Damage Caused by Insects in Wheat Stored in Steel Bins

This study was begun in June, 1933. Samples are drawn from the south quadrant of the bins once each year during the winter months to determine the comparative amounts of insect damage in wheat stored under different management practices. The damage is computed on a weight basis, and any kernel showing insect injury is classed as damaged, regardless of the extent. Insect damage determinations have been made in a total of 88 bins since this study was begun.

A summary of the data obtained from 28 bins is presented in table 3. Other bins in the management series showed similar trends. It should be borne in mind that the damage recorded in the table represents the maximum amount in the bin since the samples were taken in the portion of the grain mass where the greatest insect population was known to occur. It may be noted in table 3 that there has been a general increase in insect damage, with the rate of increase being greatest in those bins receiving no treatment. Attention is called to the fact that, even though the amount of insect damage was comparatively slight even in wheat receiving no treatment, the presence of large numbers of insects in it caused the grain to heat, with resultant sweating and molding of the surface grain. When samples are drawn from bins in this condition, both the musty odor of the surface wheat and that of the infested portion is imparted to the whole sample, causing it to be graded "sample grade". Past experience has shown that even though only a small portion of the wheat in a bin may be musty or sour, the whole mass is likely to be contaminated when the bin is emptied. For this reason the amount of indirect damage by insects is much greater than the amount of grain actually consumed.

In the last column of table 3, the total damage is indicated. This figure represents the amount of damaged wheat in average samples from the various bins, as determined by the Chicago Board of Review, and includes damage from any cause. Thus it is evident that the grain mass is much less affected by insects than that in the southwest quadrant.

The results of the insect damage study confirm previous conclusions regarding the various management practices, viz.: (1) Fumigation in August and October prevents the establishment of serious insect infestation, thus keeping the amount of insect damage to a minimum; (2) fumigation in September was successful in controlling the infestation but permitted some damage to occur prior to fumigation because of the rapid increase of insect populations during August and early in September; (3) painting the bins white prevented damage for two seasons but failed in the third; (4) the greatest amount of damage, as was expected, occurred in the uncontrolled check bins of 11.5 per cent moisture; (5) comparatively little damage occurred in wheat of 9 per cent moisture.

Table 3.--Comparative insect damage to wheat stored in steel bins, under different management practices, Hutchinson, Kansas, 1943-1946.

Bin No.	Sampling Date	Location of sample: C	S	SW	W	Surf.	Mean	Total damage* ave. sample
		Per cent damage, weight basis						
1000-bushel bins								
	No treatment, 9 per cent moisture							
1/2-3	Jan., 1944	0	0	0	0	0	0	0.6
	Feb., 1945	0.1	0.1	0.1	0.1	0	0.08	1.6
	Feb., 1946	0.3	0.4	1.0	0.9	0.5	0.62	1.6
1/2-6	Jan., 1944	0	0	0	0	0	0	1.0
	Feb., 1945	0.2	0.6	0.3	0.5	0	0.32	1.0
	Feb., 1946	2.1	0.2	0.9	0.9	1.0	1.02	1.4
	No treatment, 11.5 per cent moisture							
3-10	June, 1943	1.3	0.6	0.4	0.4	0.2	0.58	0.6
	Jan., 1944	1.0	1.4	0.2	0.2	0.1	0.58	0.7
	Feb., 1945	2.9	11.7	6.1	2.8	5.8	5.86	2.5
	Feb., 1946	2.5	4.5	5.3	0.9	5.7	3.78	5.0
3-11	June, 1943	0.3	0.2	0.3	0.2	0	0.20	0.6
	Jan., 1944	0.3	0.2	0.2	0.2	0.2	0.22	0.5
	Feb., 1945	3.9	8.8	4.3	2.5	2.9	4.48	2.0
	Feb., 1946	10.3	9.8	19.8	23.0	6.1	13.80	3.0
	White walls and roof							
1/2-2	June, 1943	0.1	0.2	0.1	0.1	0.1	0.12	0.7
	Jan., 1944	0.1	0.1	0	0	0	0.04	1.0
	Feb., 1945	1.4	4.1	7.9	4.2	10.9	5.70	0.9
	Feb., 1946	2.7	4.3	4.2	2.8	6.4	4.08	1.0
1-3	June, 1943	0.6	0.2	0.2	0.4	0.2	0.32	0.6
	Jan., 1944	0.5	0.5	0.3	0.3	0.5	0.42	0.5
	Feb., 1945	0.9	1.2	1.9	2.6	2.4	1.80	0.7
	Feb., 1946	2.7	2.6	3.7	2.8	4.5	3.26	0.7
	Fumigation in August							
1-5	Feb., 1945	1.4	1.2	1.5	2.1	1.3	1.50	0.8
	Feb., 1946	1.7	2.4	4.1	1.2	1.2	2.12	6.6
4-11	Feb., 1945	1.3	1.1	1.1	1.1	1.3	1.18	0.5
	Feb., 1946	0.7	2.5	1.0	1.2	3.6	1.80	1.0

* Commercial grade sample, graded by Chicago Board of Review from whole bin.

(continued)

Table 3 (continued)

Bin No.	Sampling date	Location of sample: C	S	SW	W	Surf.	Mean	Total damage* ave. sample
		Per cent damage, weight basis						
	Fumigation in September							
3-13	June, 1943	0.9	0.2	0.1	0.2	0.1	0.30	0.4
	Jan., 1944	0.7	0.2	0.2	0.2	0.2	0.30	1.0
	Feb., 1945	0.9	0.7	1.1	1.4	1.1	1.04	0.8
	Feb., 1946	3.4	3.0	0.5	0.8	1.1	1.76	0.8
4-12	June, 1943	0.2	0.2	0.2	0.2	0.8	0.32	0.4
	Jan., 1944	0.2	0.2	0.1	0.2	0.2	0.18	0.8
	Feb., 1945	2.7	1.1	2.9	1.2	1.4	1.86	1.0
	Feb., 1946	2.3	3.1	3.8	0.6	3.7	2.70	1.0
	Fumigation, August and October							
3-12	June, 1943	0.2	0.2	0.1	0.1	0.2	0.16	0.7
	Jan., 1944	0.2	0.2	0.1	0.3	0.2	0.20	0.7
	Feb., 1945	1.0	0.7	0.6	1.1	1.1	0.90	1.0
	Feb., 1946	0.4	0.3	0.9	0.5	0.9	0.60	0.8
1/2-5	Jan., 1944	0	0	0	0.1	0	0.02	0.5
	Feb., 1945	0	0	0.1	0	0	0.02	1.0
	Feb., 1946	0	0.8	0.3	0	0	0.22	0.5
4-5	Jan., 1944	0	0.2	0	0	0.1	0.06	0.3
	Feb., 1945	0.2	0.1	0.1	0.4	0	0.16	0.4
	Feb., 1946	0.5	0.1	0.3	0.5	0.4	0.36	0.4
	Turn, clean, fumigate in September							
3-15	June, 1943	0.4	0.5	0.2	0.1	0.2	0.28	0.6
	Jan., 1944	0.1	0.1	0.2	0.2	0.1	0.14	1.2
	Feb., 1945	0.6	0.5	0.7	0.6	1.1	0.70	0.4
	Feb., 1946	0.7	1.3	1.6	1.2	1.6	1.28	1.5
2740-bushel bins								
	White walls and roof							
11-9	June, 1943	0.2	0.3	0.2	0.1	0.1	0.18	5.0
	Jan., 1944	0.4	0.2	0.2	0.2	0.2	0.24	5.0
	Feb., 1946	3.3	4.6	4.9	2.4	9.4	4.92	--
12-8	June, 1943	0	0.4	0.3	0.3	0.2	0.24	2.8
	Jan., 1944	0.2	0.3	0.2	0.4	0.2	0.26	2.5
	Feb., 1946	1.5	1.0	1.6	0.6	2.0	1.34	--

(continued)

Table 3 (continued)

Bin No.	Sampling date	Location of sample: C	S	EM	W	Surf.	Mean	Total damage* ave. sample
		Per cent damage, weight basis						
	Fumigation in September							
3-13	June, 1943	0.9	0.2	0.1	0.2	0.1	0.30	0.4
	Jan., 1944	0.7	0.2	0.2	0.2	0.2	0.30	1.0
	Feb., 1945	0.9	0.7	1.1	1.4	1.1	1.04	0.8
	Feb., 1946	3.4	3.0	0.5	0.8	1.1	1.76	0.8
4-12	June, 1943	0.2	0.2	0.2	0.2	0.8	0.28	0.4
	Jan., 1944	0.2	0.2	0.1	0.2	0.2	0.18	0.8
	Feb., 1945	2.7	1.1	2.9	1.2	1.4	1.88	1.0
	Feb., 1946	2.8	3.1	3.8	0.6	3.7	2.70	1.0
	Fumigation, August and October							
3-12	June, 1943	0.2	0.2	0.1	0.1	0.2	0.14	0.7
	Jan., 1944	0.2	0.2	0.1	0.3	0.2	0.20	0.7
	Feb., 1945	1.0	0.7	0.8	1.1	1.1	0.90	1.0
	Feb., 1946	0.4	0.3	0.8	0.5	0.3	0.80	0.8
1/2-6	Jan., 1944	0	0	0	0.1	0	0.02	0.6
	Feb., 1945	0	0	0.1	0	0	0.02	1.0
	Feb., 1946	0	0.8	0.3	0	0	0.22	0.8
4-6	Jan., 1944	0	0.2	0	0	0.1	0.06	0.8
	Feb., 1945	0.2	0.1	0.1	0.4	0	0.16	0.4
	Feb., 1946	0.5	0.1	0.3	0.5	0.4	0.36	0.4
	Turn, clean, fumigate in September							
3-15	June, 1943	0.4	0.3	0.2	0.1	0.2	0.26	0.6
	Jan., 1944	0.1	0.1	0.2	0.2	0.1	0.14	1.2
	Feb., 1945	0.6	0.3	0.7	0.6	1.1	0.70	0.4
	Feb., 1946	0.7	1.3	1.6	1.2	1.0	1.28	1.2
	2740-Quonset bins							
	White walls and roof							
11-3	June, 1943	0.2	0.3	0.2	0.1	0.1	0.18	5.0
	Jan., 1944	0.4	0.3	0.2	0.2	0.2	0.24	5.0
	Feb., 1946	3.3	4.8	4.9	2.4	3.4	4.82	--
12-8	June, 1943	0	0.4	0.3	0.3	0.2	0.24	3.8
	Jan., 1944	0.2	0.3	0.2	0.4	0.2	0.26	2.8
	Feb., 1946	1.8	1.0	1.8	0.8	2.0	1.34	--

(continued)

Table 3 (continued).

Bin No.	Sampling date	Location of sample: C	S	SW	W	Surf.	Mean (Per cent damage, weight basis)	Total damage* ave. sample
	Painted white and grouped							
7-8 (SW bin in group)	June, 1943	0.1	0.1	0.2	0.1	0.2	0.14	1.0
	Jan., 1944	0	0.3	0.2	0.4	0.2	0.22	0.5
	Feb., 1946	1.2	2.3	1.9	1.0	3.2	1.92	0.7
7-9 (NW bin in group)	June, 1943	0.3	0.2	0.2	0.2	0.2	0.22	0.8
	Jan., 1944	0.2	0.5	0.3	0.2	0.3	0.30	0.6
	Feb., 1946	1.5	0.5	0.5	0.7	1.4	0.92	0.6
8-7 (SE bin in group)	June, 1943	0.1	0.2	0.1	0.1	0.2	0.14	0.7
	Jan., 1944	0.4	0.2	0.4	0.2	0.1	0.26	0.8
	Feb., 1946	0.8	0.2	0.5	0.3	0.6	0.48	0.7
8-8 (NE bin in group)	June, 1943	0.2	0.1	0.3	0.1	0.2	0.18	0.5
	Jan., 1944	0.2	0.3	0.3	0.4	0.3	0.30	0.6
	Feb., 1946	0.2	0.8	0.7	0.2	1.5	0.68	1.0
	Fumigation in August							
7-7	Apr., 1944	0.1	0.2	0.1	0.1	0	0.10	0.4
	Feb., 1946	0.4	0.7	0.4	0.8	0.7	0.60	--
8-2	Apr., 1944	0	0	0	0	0.1	0.02	0.4
	Feb., 1946	0.2	0.4	0.2	0.5	0.6	0.38	0.4
8-3	Apr., 1944	0.1	0	0	0	0	0.02	0.5
	Feb., 1946	0.5	0.3	0.6	0.7	0.8	0.56	0.4
8-6	Apr., 1944	0.1	0.1	0.1	0	0.1	0.08	0.3
	Feb., 1946	0.7	0.5	1.2	0.2	0.7	0.66	0.3
	Fumigation in September							
7-3	Apr., 1944	0.3	0.2	0.1	0.1	0.2	0.18	1.0
	Feb., 1946	0.9	1.5	1.9	0.7	1.4	1.28	0.8
11-10	June, 1943	0.3	0.1	0.1	0.1	0	0.12	1.5
	Jan., 1944	0.2	0.2	0.2	0.2	0.2	0.20	3.5
	Feb., 1946	1.8	4.6	1.1	1.3	3.5	2.46	4.0
11-11	June, 1943	0.3	0.1	0.6	0.2	0.2	0.28	1.2
	Jan., 1944	0.6	0.2	0.2	0.2	0.2	0.28	2.4
	Feb., 1946	2.4	0.8	0.6	0.3	0.8	0.98	5.0
	Fumigation in August and October							
9-1	June, 1943	0.1	0.2	0.1	0.1	0.2	0.12	0.3
	Jan., 1944	0.3	0.1	0.1	0.1	0.2	0.16	0.4
	Feb., 1946	0.3	0.4	0.5	0.2	0.9	0.42	0.5

Effect of Temperature, Moisture, and Dockage on the Survival and Reproduction of the Red Flour Beetle*

In Report No. 18 partial results were reported relative to breeding experiments of the red flour beetle at a constant temperature of 65° F. These experiments were completed during the quarter, and data on the percentage of survival of adults are summarized in table 4. In the 9% moisture wheat adult survival increases in direct proportion to the amount of dockage present. In clean wheat of this moisture content there were no survivors at the end of 19 weeks whereas in the wheat with the 8% dockage the survival was 85%. In the 12 and 15% wheat the effect of dockage on survival was not so evident.

In table 5 is given a record of the eggs laid by 10 female red flour beetles at this temperature in flour of 9, 12, and 15% moisture, over a period of 12 weeks. A greater number of eggs were laid in the 12 and 15% moisture flour than in the 9% moisture flour. At this temperature the development of the larval stage is extremely slow and in the adult survival test series referred to, no pupae were recovered from any lot during the 19-week period over which observations were made.

Table 4.--Percentage of survival of the red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 65° F. (Continued from Oct.-Dec. 1945 Report).

Moisture content of wheat and food media	Percentage survival after								
	11 weeks	12 weeks	13 weeks	14 weeks	15 weeks	16 weeks	17 weeks	18 weeks	19 weeks
9% Wheat									
Clean wheat	0	0	0	0	0	0	0	0	0
Same + 0.5% Dock.	50	45	30	30	20	20	20	15	15
Same + 1.0% "	75	70	65	65	55	55	45	45	35
Same + 2.0% "	70	55	55	55	55	55	50	40	40
Same + 4.0% "	85	75	75	75	75	75	75	75	75
Same + 8.0% "	100	100	95	95	95	95	90	85	85
12% Wheat									
Clean wheat	85	85	85	85	70	70	65	45	45
Same + 0.5% Dock.	75	75	75	75	75	75	75	75	75
Same + 1.0% "	95	90	90	90	90	90	90	90	90
Same + 2.0% "	90	85	80	80	80	80	75	75	75
Same + 4.0% "	85	75	75	75	75	75	75	75	75
Same + 8.0% "	90	90	90	90	90	90	90	90	90
15% Wheat									
Clean wheat	85	85	85	85	85	85	80	75	75
Same + 0.5% Dock.	95	95	95	95	95	95	95	95	95
Same + 1.0% "	95	95	90	90	90	90	90	90	90
Same + 2.0% "	80	80	80	80	80	80	80	80	80
Same + 4.0% "	75	75	70	70	70	70	50	40	40
Same + 8.0% "	60	55	55	55	55	55	55	55	50

* -- Reported by R. T. Cotton and J. C. Frankenfeld.

Effect of Temperature, Moisture, and Cookies on the Survival and Reproduction of the Red Flour Beetle*

In Report No. 18 partial results were reported relative to breeding experiments of the red flour beetle at a constant temperature of 85° F. These experiments were completed during the quarter, and data on the percentage of survival of adults are summarized in table 4. In the 9% moisture wheat adult survival increases in direct proportion to the amount of cookie present. In clean wheat of this moisture content there were no survivors at the end of 12 weeks whereas in the wheat with the 8% cookie the survival was 88%. In the 12 and 15% wheat the effect of cookie on survival was not so evident.

In table 5 is given a record of the eggs laid by 10 female red flour beetles at this temperature in flour of 9, 12, and 15% moisture, over a period of 12 weeks. A greater number of eggs were laid in the 12 and 15% moisture flour than in the 9% moisture flour. At this temperature the development of the larval stage is extremely slow and in the adult survival experiment referred to, no pupae were recovered from any lot during the 12-week period over which observations were made.

Table 4.--Percentage of survival of the red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of cookies at 85° F.
(Continued from Oct.-Dec. 1936 report).

Moisture content of wheat and food media	Percentage survival after											
	11 weeks	12 weeks	13 weeks	14 weeks	15 weeks	16 weeks	17 weeks	18 weeks	19 weeks	20 weeks	21 weeks	22 weeks
9% Wheat												
Clean wheat	0	0	0	0	0	0	0	0	0	0	0	0
Same + 0.5% Cookie	50	45	30	30	20	20	20	20	15	15	15	15
Same + 1.0% "	75	70	65	85	85	85	60	60	55	55	55	55
Same + 2.0% "	70	65	65	75	75	55	50	50	40	40	40	40
Same + 4.0% "	85	75	75	75	75	75	75	75	75	75	75	75
Same + 8.0% "	100	100	95	90	90	90	90	90	90	85	85	85
12% Wheat												
Clean wheat	95	95	85	85	70	70	65	15	15	15	15	15
Same + 0.5% Cookie	75	75	75	75	75	75	75	75	75	75	75	75
Same + 1.0% "	95	90	90	90	90	90	90	90	90	90	90	90
Same + 2.0% "	90	85	80	90	90	90	80	75	75	75	75	75
Same + 4.0% "	85	75	75	75	75	75	75	75	75	75	75	75
Same + 8.0% "	90	90	90	90	90	90	90	90	90	90	90	90
15% Wheat												
Clean wheat	85	95	85	85	85	85	85	80	75	75	75	75
Same + 0.5% Cookie	95	85	95	95	95	95	95	95	95	95	95	95
Same + 1.0% "	95	95	90	90	90	90	90	90	90	90	90	90
Same + 2.0% "	80	80	80	80	80	80	80	80	80	80	80	80
Same + 4.0% "	75	70	70	70	70	70	70	70	70	70	70	70
Same + 8.0% "	80	65	65	65	65	65	65	65	65	65	65	65

* -- Reported by R. T. Cotton and L. C. Frankenfeld.

Table 5.--Egg laying record of 10 female Tribolium castaneum over a period of 12 weeks at 65° F.

Date	Number eggs laid by 10 females in		
	9% moisture flour	12% moisture flour	15% moisture flour
12/21/45	0	0	7
12/27/45	0	5	3
1/ 4/46	0	10	5
1/11/46	0	6	5
1/18/46	0	8	5
1/25/46	0	9	5
2/ 1/46	6	11	10
2/ 8/46	8	13	13
2/15/46	4	14	8
2/22/46	10	8	9
3/ 1/46	14	7	10
3/ 8/46	32	18	27
Totals	74	109	107

The survival and reproduction of the red flour beetle in a similar series held at a constant temperature of 75° F. was reported on, in Report No. 18 for a period of 16 weeks. Observations on this series have now been completed and final data are given in table 6. As in the series held at 65° F, the amount of dockage present did not affect adult survival except in the 9% moisture series where survival was in direct proportion to the amount of dockage present.

Reproduction was not extensive at this temperature but increased with an increase in moisture content and with an increase in the amount of dockage present.

Egg laying records of the red flour beetle and the confused flour beetle at this temperature are summarized in table 7 for a period of 24 weeks to show the effect of changing the food at weekly and monthly intervals on fecundity. It will be noted that there was little difference between the number of eggs laid by adult females when the food was changed at weekly or monthly intervals. However, when the food was unchanged, a very much smaller number of eggs were laid by both species.

The confused flour beetle adults laid on an average nearly twice as many eggs over the period as the red flour beetle.

Table 6.--Percentage of survival of the red flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 75° F.

Moisture content of wheat and food media	Percentage survival after 17 weeks	18 weeks	19 weeks	Total progeny after 19 weeks
9% Wheat				
Clean wheat	0	0	0	0
Same + 0.5% Dockage	30	20	5	11
Same + 1.0% "	65	65	65	9
Same + 2.0% "	80	80	80	27
Same + 4.0% "	95	90	90	39
Same + 8.0% "	85	75	75	45
12% Wheat				
Clean wheat	80	75	65	17
Same + 0.5% Dockage	90	90	90	67
Same + 1.0% "	95	95	95	40
Same + 2.0% "	95	95	95	79
Same + 4.0% "	80	80	80	66
Same + 8.0% "	90	90	80	95
15% Wheat				
Clean wheat	85	85	85	24
Same + 0.5% Dockage	95	90	90	70
Same + 1.0% "	90	90	90	108
Same + 2.0% "	90	90	90	146
Same + 4.0% "	90	85	85	136
Same + 8.0% "	95	90	90	157

Table 7.--Egg laying record of 10 female T. castaneum and 10 female T. confusum over a period of 24 weeks at 75° F. and 46% R.H.

Egg laying period	Number eggs laid by 10 females of T. castaneum: Food changed weekly	Food changed every 4 weeks	Food unchanged	T. confusum: Food changed weekly	Food changed every 4 weeks	Food unchanged
1-12 weeks	1759	1561	783	2503	2405	1127
13th week	192	159	106	227	248	121
14th week	194	143	118	271	259	150
15th week	144	112	94	292	298	161
16th week	129	163	94	310	331	175
17th week	73	162	93	312	363	183
18th week	67	117	112	288	310	175
19th week	80	93	128	209	296	182
20th week	31	82	96	169	254	184
21st week	10	48	111	158	237	131
22nd week	26	75	100	119	193	179
23rd week	10	46	80	129	190	161
24th week	11	38	56	113	157	132
Totals	2746	2799	1971	5100	5541	3061
Ave. per female	274.6	279.9	197.1	510	554.1	306.1

In another series of tests with both the red flour beetle and the confused flour beetle a constant temperature of 95° F. was maintained. Data regarding the survival and reproduction of these two species at this temperature are given in tables 8, 9, 10, and 11.

It will be noted that this temperature is not favorable for the survival of either species. The percentage of dockage present affects survival only in the 9% moisture series, an observation that seems to hold true at all temperatures.

Up to a certain point reproduction increases with both an increase in moisture and an increase in the amount of dockage present. Reproduction is rapid at this temperature and the first pupae were recovered at the end of the third week.

Egg laying records of 10 female red flour beetles for an eleven-week period are given in table 12. It will be noted that where the food was changed at weekly intervals egg oviposition took place at a much faster rate than where it was not changed.

Table 8.--Percentage of survival of T. castaneum in 9, 12, and 15% moisture wheat with varying amounts of dockage at 95° F.

Moisture content of wheat and food media	Percent survival after 1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks	11 weeks
9% Wheat											
Clean wheat	15	0									
Same + 0.5% Dock.	70	55	45	30	25	15	0				
Same + 1.0% "	80	70	65	60	55	50	30	20	10	10	10
Same + 2.0% "	80	70	70	25	25	20	15	15	5	0	
Same + 4.0% "	95	80	60	0							
Same + 8.0% "	80	75	75	55	55	55	55	55	55	50	50
12% Wheat											
Clean wheat	95	90	70	40	15	15	15	10	5	5	5
Same + 0.5% Dock.	95	85	80	0							
Same + 1.0% "	90	85	20	0							
Same + 2.0% "	85	55	15	0							
Same + 4.0% "	95	25	20	20	20	20	20	20	20	20	20
Same + 8.0% "	100	90	10	10	10	10	10	10	10	10	10
15% Wheat											
Clean wheat	100	100	100	90	85	85	80	65	55	35	20
Same + 0.5% Dock.	100	100	95	0							
Same + 1.0% "	100	95	90	0							
Same + 2.0% "	100	25	25	25	25	25	25	25	25*		
Same + 4.0% "	100	20	20	20	20	20	20	20	20*		
Same + 8.0% "	100	80	0								

* Started 2 weeks later than rest.

Table 9.--Weekly recovery of T. castaneum from 9, 12, and 15% moisture wheat with varying amounts of dockage at 95° F.

Moisture content of wheat and food media	Number of pupae recovered after 3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	Total
9% Wheat										
Clean wheat										
Same + 0.5% Dockage				2	7	4	1	1	0	15
Same + 1.0% "			2	7	14	9	0	1	2	3	38
Same + 2.0% "			1	15	19	6	5	1	0	1	48
Same + 4.0% "			4	20	1	5	4	2	0	0	36
Same + 8.0% "			9	35	16	3	23	2	12	7	107
12% Wheat										
Clean wheat			7	20	7	9	0	0	0	1	44
Same + 0.5% Dockage	9	24	24	16	10	0	0	0	0	0	83
Same + 1.0% "	8	23	25	1	0	0	0	0	0	0	57
Same + 2.0% "	1	12	12	1	9	4	0	13	0	0	52
Same + 4.0% "			1	14	76	17	17	19	16	160
Same + 8.0% "	3	27	69	2	57	53	8	68	28	313
15% Wheat										
Clean wheat	34	52	23	15	7	7	1	2	3	144
Same + 0.5% Dockage	38	29	32	0	2	2	0	0	0	103
Same + 1.0% "	27	28	16	0	2	0	0	0	0	73
Same + 2.0% "	4	7	57	34	8	21	6*			137
Same + 4.0% "		1	71	64	6	41	2*			185
Same + 8.0% "	11	18	73	2	13	0	1	0	0	118

* Started 2 weeks later than rest.

Table 10.--Percentage of survival of the confused flour beetle in 9, 12, and 15% moisture wheat with varying amounts of dockage at 95° F.

Moisture content of wheat and food media	Percent survival after 1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks	11 weeks
9% Wheat											
Clean wheat	25	0									
Same + 0.5% Dock.	70	70	70	50	10	0					
Same + 1.0% "	75	75	75	75	65	35	15	10	0		
Same + 2.0% "	75	75	75	75	50	25	0				
Same + 4.0% "	40	40	40	40	35	30	25	25	15	15	15
Same + 8.0% "	100	95	80	80	70	65	50	50	45*		
12% Wheat											
Clean wheat	95	75	75	45	10	10	5	5	5	5	0
Same + 0.5% Dock.	85	80	80	45	40	30	25	25	20	20	20
Same + 1.0% "	85	85	85	20	20	20	20	15	10	10	10
Same + 2.0% "	95	95	95	0							
Same + 4.0% "	100	100	25	0							
Same + 8.0% "	85	85	70	0							
15% Wheat											
Clean wheat	100	100	100	100	100	80	65	60	40	35	35
Same + 0.5% Dock.	100	30	30	30	30	25	25	25	20	15	5
Same + 1.0% "	100	100	95	95	95	90	80	65	30*		
Same + 2.0% "	85	60	60	60	60	60	55	55	55*		
Same + 4.0% "	95	70	70	60	55	55	55	55	50*		
Same + 8.0% "	95	90	0	0							

* Started 2 weeks later than rest.

Table 11.--Weekly Recovery of T. confusum from 9, 12, and 15% moisture wheat with varying amounts of dockage at 95° F.

Moisture content of wheat and food media	Number pupae recovered after									
	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	Total
9% Wheat										
Clean wheat	00	0	0							0
Same + 0.5% Dock.	0	1	8	0	10	7	1	0	0	27
Same + 1.0% "	0	5	25	20	13	28	5	2	3	101
Same + 2.0% "	0	3	23	24	23	4	3	2	1	83
Same + 4.0% "	0	2	49	22	18	7	5	5	7	115
Same + 8.0% "	0	60	125	49	21	30	22*			307
18% Wheat										
Clean wheat	3	1	12	18	3	1	0	0	1	39
Same + 0.5% Dock.	30	36	19	3	7	4	4	0	0	103
Same + 1.0% "	43	33	37	7	3	7	9	13	7	159
Same + 2.0% "	17	20	20	0	0	1	1	12	10	81
Same + 4.0% "	4	3	1	0	0	0	0	2	0	10
Same + 8.0% "	0	13	51	1	1	2	0	0	0	68
15% Wheat										
Clean wheat	31	50	31	10	19	12	4	8	29	204
Same + 0.5% Dock.	29	38	29	5	14	6	11	18	18	168
Same + 1.0% "	24	73	74	23	5	33	22*			254
Same + 2.0% "	12	82	52	18	28	54	23*			269
Same + 4.0% "	11	106	75	12	4	86	36*			330
Same + 8.0% "	21	55	47	3	4	1	0	1	0	132

Table 12.--Egg laying record of 10 female Tribolium castaneum during 11-week period at 95° F. Moisture content of flour 12%.

Date	Number eggs laid by 10 females	
	Food changed weekly	Food unchanged
1-17-46	18	25
1-21-46	184	137
1-23-46	191	116
1-25-46	120	63
1-29-46	304	122
2- 1-46	174	138
2- 6-46	248	130
2- 8-46	73	70
2-13-46	84	75
2-15-46	30	48
2-18-46	62	64
2-22-46	13	57
2-26-46	47	42
3- 1-46	72	8
3- 5-46	34	15
3-88-46	64	18
3-12-46	7	0
3-15-46	8	0
3-19-46	6	0
3-22-46	3	0
3-26-46	0	0
3-29-46	0	0
Totals	1742	1128